Radiation Safety at the 88-Inch Cyclotron (EH&S 440)

- This course is designed to acquaint general users of the 88-Inch Cyclotron with the DOE regulations, postings and additional training which may necessary in order to work at the accelerator facility and with the specific radiation hazards they may encounter at the Cyclotron.
- This course covers the material presented in LBNL EH&S 405, General Employee Radiation Training (GERT), and in EH&S 450, Dosimetry Training, and credit is given for these classes automatically when the test for this course is completed with at least 80% correct answers.

Is this course enough?

You must take additional training if you:

- are an LBNL employee
- work in Bldg. 88 as a Participating Guest more than 30 days/year
- work in a Radiation Area at the 88-Inch Cyclotron (> 5mR/hr at 30 cm.)
- need to work with sealed or unsealed radioactive material
- irradiate samples which have the potential to become activated above the levels defined by DOE
- generate hazardous or mixed radioactive waste

Talk to Peggy if you think you might qualify for more training!

Outline of Training

- Review of Radiation Fundamentals
- DOE Postings and Definitions
- LBNL Terminology Defined
- 88″ Hazards
  - Prompt Ionizing Radiation
  - Induced Radiation
  - Radioactive Sources
  - Unsealed Radioactive material
- Non-rad Hazards at the Cyclotron
- Contacts

I. Radiation Fundamentals

Radiation is energy in motion

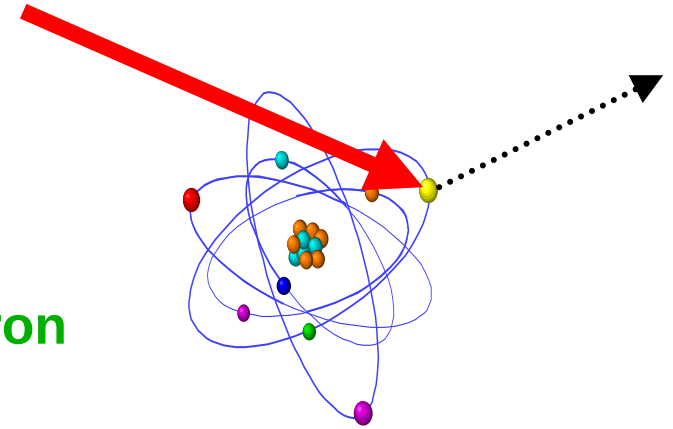
low energy

non-ionizing

high energy

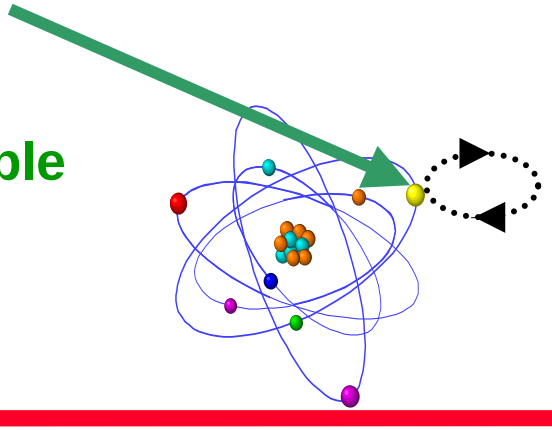
ionizing radiation

Ionizing radiation



- High energy radiation
  - Electromagnetic waves:
  - Gamma-rays, x-rays, UV
  - Particles: alpha, beta, neutron
- Ejects electrons from atoms
  - Produces an altered atom - an ion

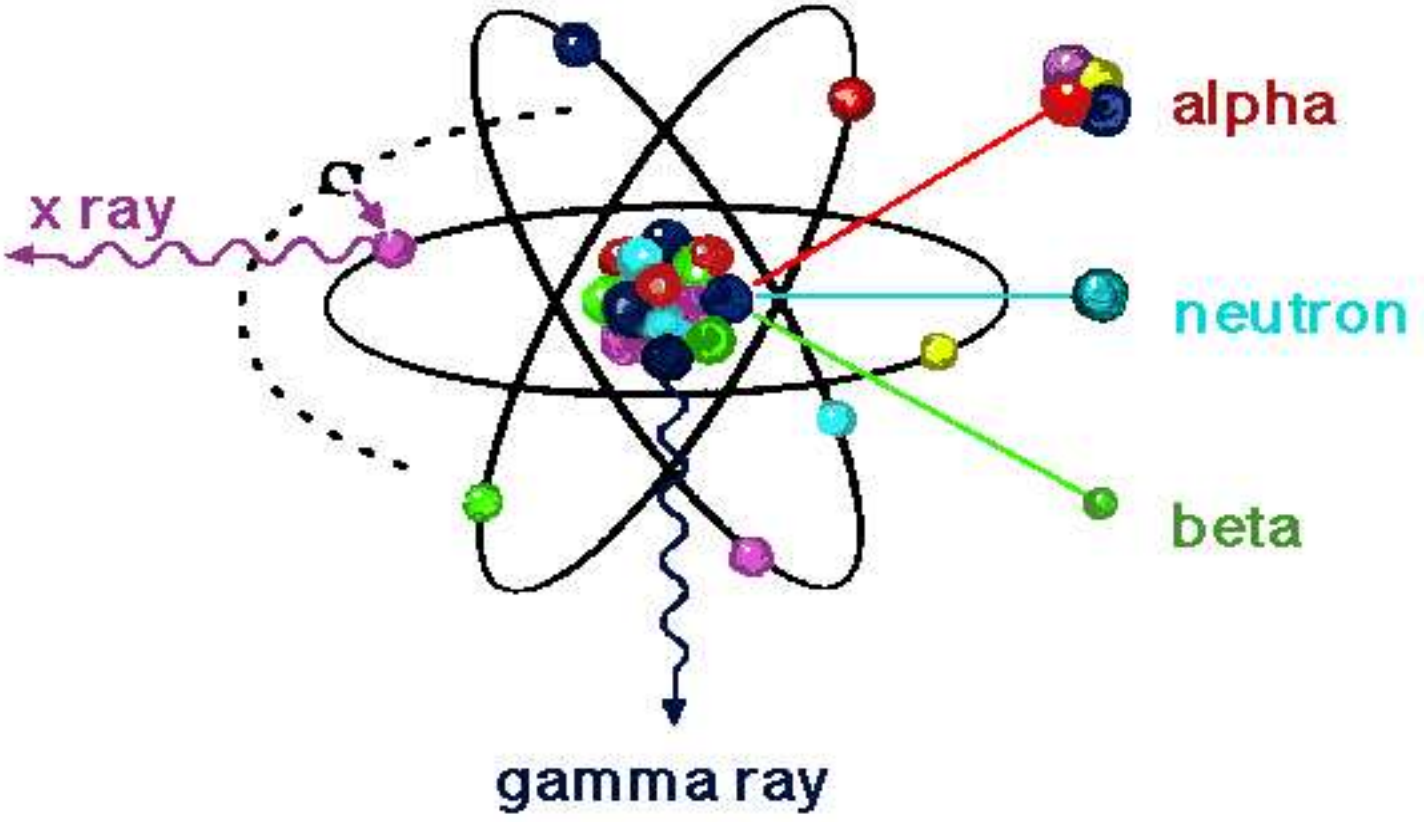
Non-ionizing radiation



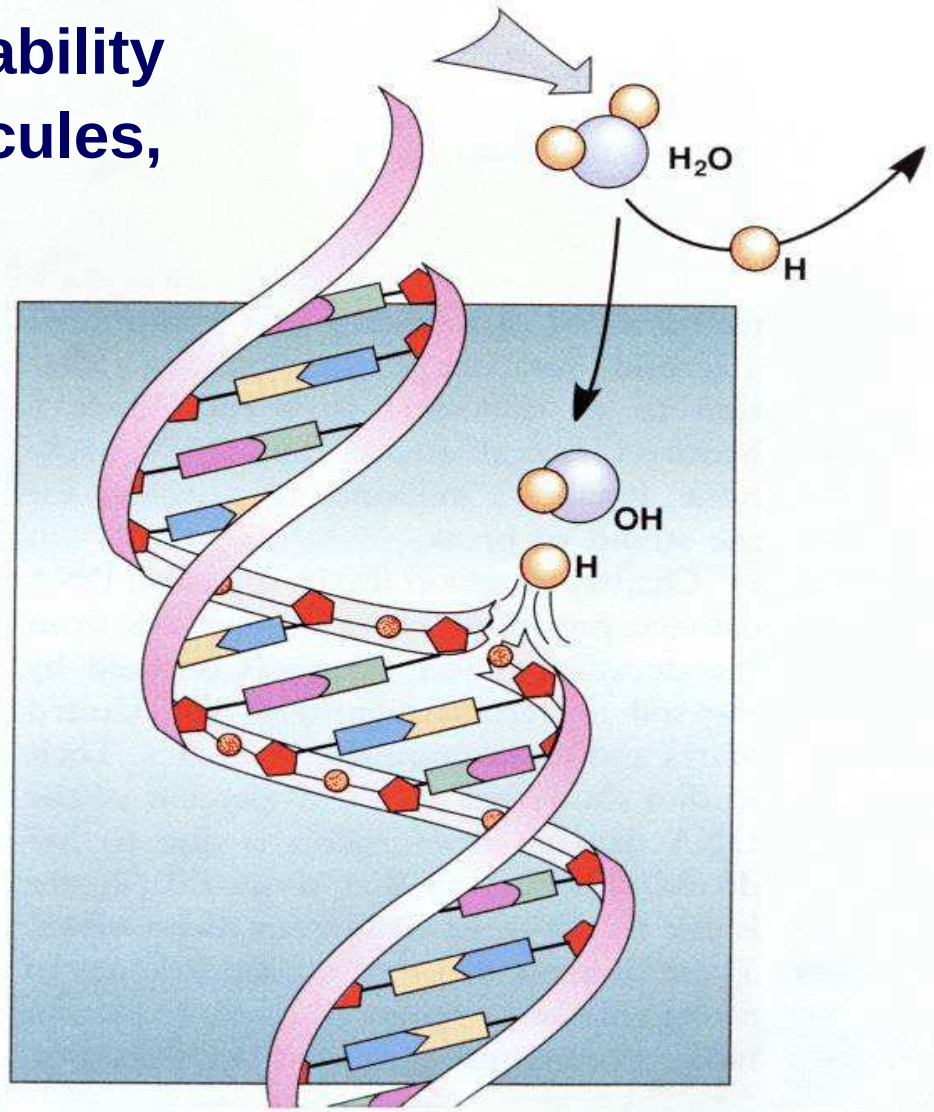
- Low energy
  - Lasers, RF, microwaves, IR, visible
- Excites electrons
  - Produces heat

Ionizing Radiation

Unstable atoms and nuclei emit ionizing radiations



Ionizing radiation has the ability to ionize* atoms and molecules, possibly altering structure and function.



*** ionize = produce positive and negative electrical charge**

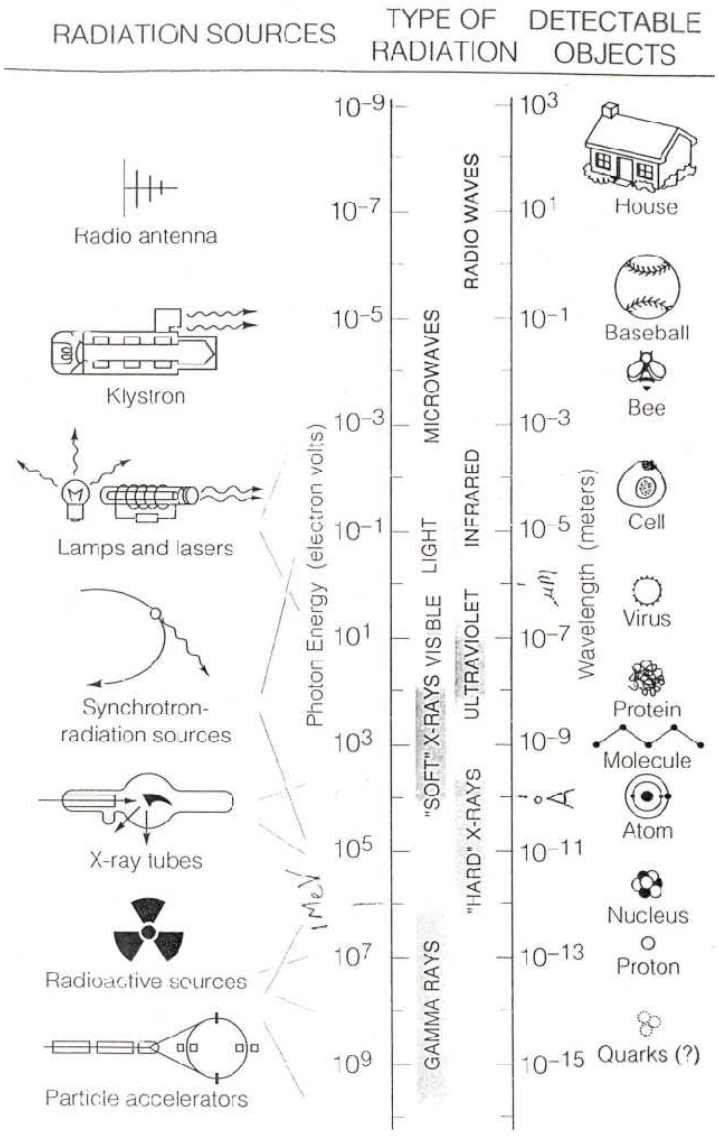
Sources of Ionizing Radiation

Radioactive materials

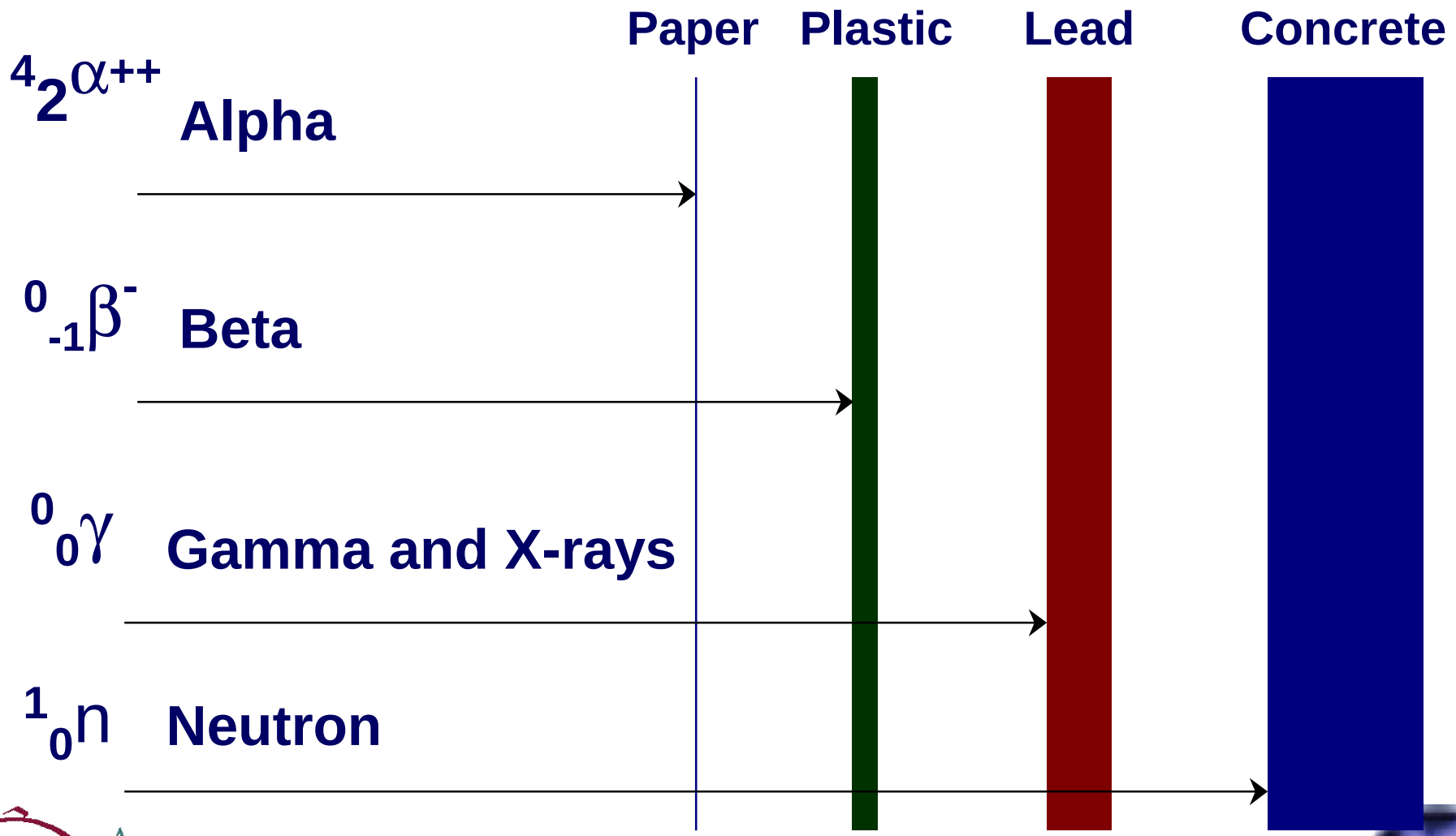
- Naturally occurring (uranium, carbon-14, …)
- Artificial (activated by neutrons from a reactor or accelerator beam)

Radiation Producing Machines

- Unintentional emitters (TVs, VDTs, EMs)
- Intentional emitters
- X-ray machines (characteristic, bremstrahlung)
- Accelerators (ion beams, neutrons, x-rays)

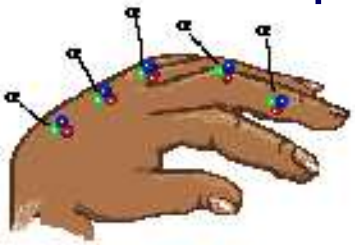

RADIATION SOURCES
TYPE OF RADIATION
DETECTABLE OBJECTS
Radio antenna
Klystron
Lamps and lasers
Synchrotron-radiation sources
X-ray tubes
Radioactive sources
Particle accelerators
Photon Energy (electron volts)
10⁻⁹
10⁻⁷
10⁻⁵
10⁻³
10⁻¹
10¹
10³
10⁵
10⁷
10⁹
MeV
GAMMA RAYS
"HARD" X-RAYS
"SOFT" X-RAYS
ULTRAVIOLET
VISIBLE LIGHT
INFRARED
MICROWAVES
RADIO WAVES
Wavelength (meters)
10³
10¹
10⁻¹
10⁻³
10⁻⁵
μ
10⁻⁷
10⁻⁹
Å
10⁻¹¹
10⁻¹³
10⁻¹⁵
House
Baseball
Bee
Cell
Virus
Protein
Molecule
Atom
Nucleus
Proton
Quarks (?)

Types of Radiation

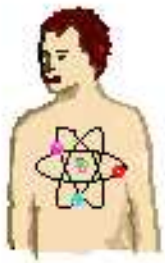


Alpha Radiation Is Only a Hazard When Inside Your Body (Internal Hazard)

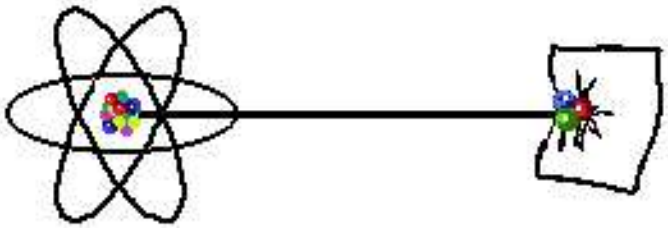
Your skin will stop it



can't penetrate skin



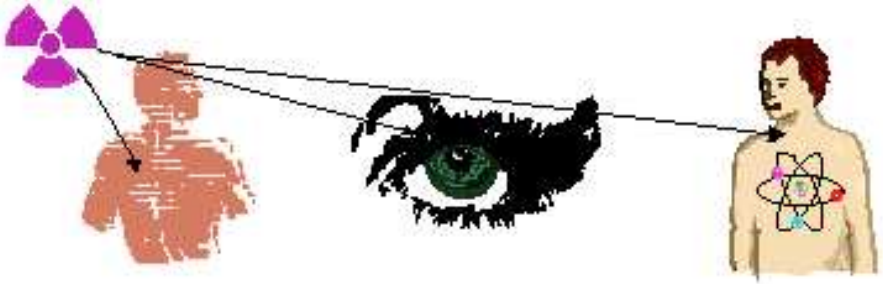
internal hazard



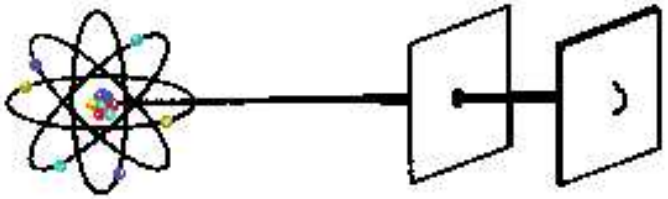
stopped by paper

found in soil, radon and other radioactive materials

Beta Radiation Is a Skin, Eye and Internal Hazard



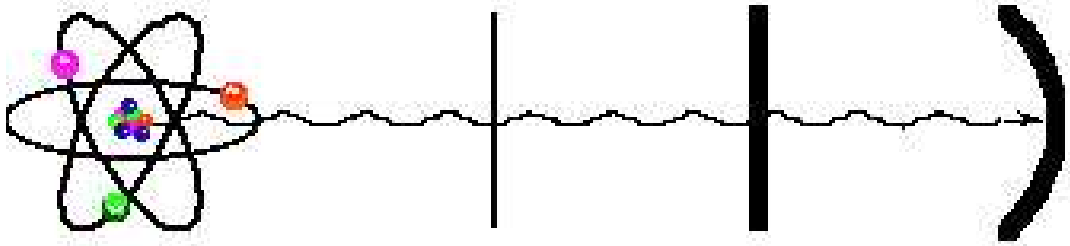
skin, eye and internal hazard



stopped by plastic

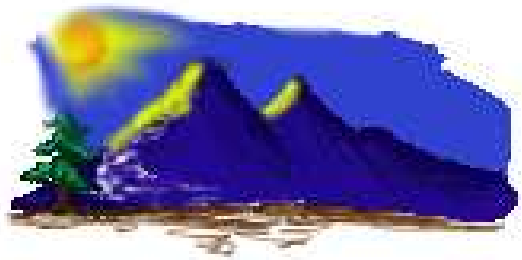
found in natural food, air and water

X and Gamma Radiation Are Penetrating Radiation and an EXTERNAL HAZARD.

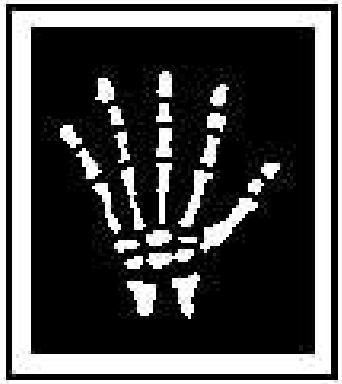


stopped by lead

found in medical uses



naturally present in soil and cosmic radiation



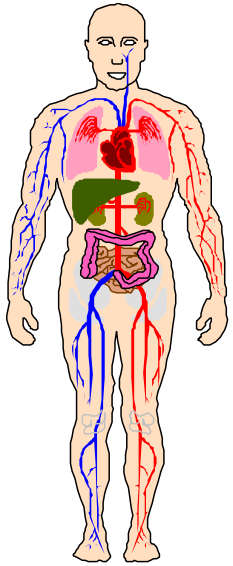
Quality Factors

Rad X Q = REM

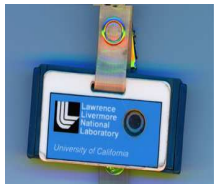
Gamma X-ray	1
Beta	1
Neutron	3-20
Alpha	20

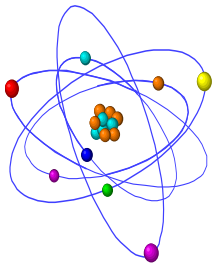
Radiation Quantities and Units

Radiation Exposure
Qty: Exposure
Unit: Roentgen
1 R = 1esu/cc
now obsolete



Radiation Absorbed Dose
Qty: Dose
Unit: rad (Gray)
1 rad - 1000 mrad
1 rad = 100 erg/gram
1 Gy=100 rad





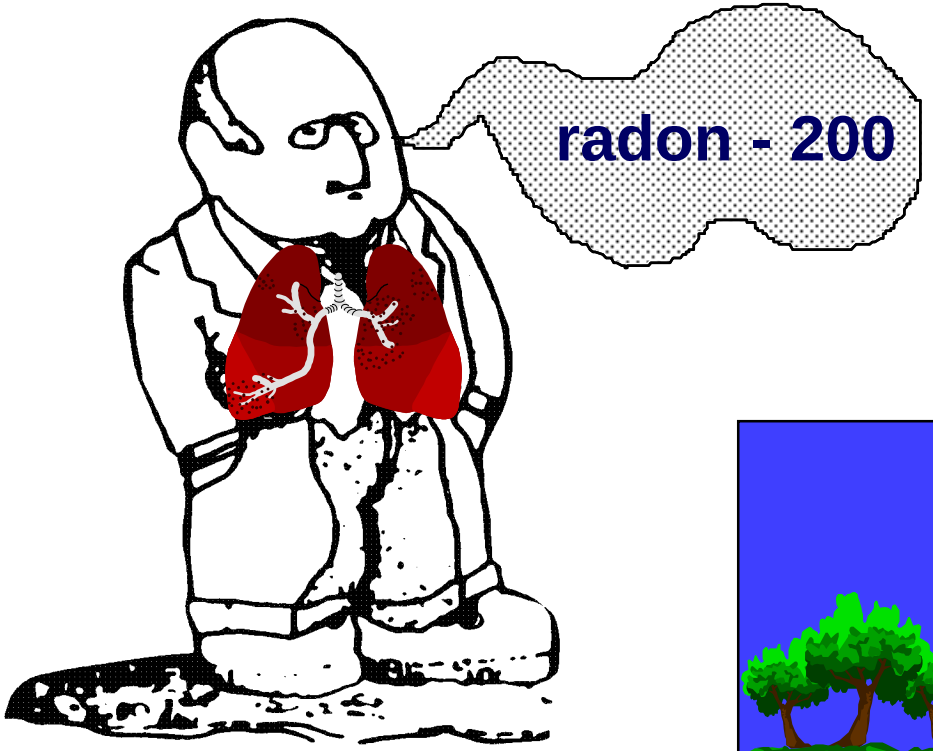
Radioactivity
Qty: Activity
Unit: Curie (Bequerel)
1 Ci = 1000 mCi
1 Bq = 1 dis per sec
1 Ci = 3.7 e10 Bq

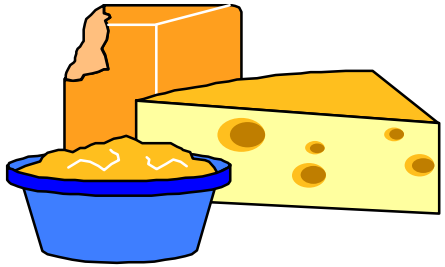
Radiation Risk
Qty: Dose Equivalent
Unit: rem (Sievert)
1 rem = 1000 mrem
1 Sv=100 rem

radiation equivalent man

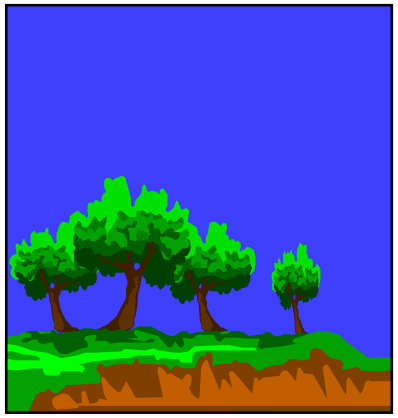
Background and Manufactured Radiation In the U.S. Contributes 360 mrem per year

cosmic - 28

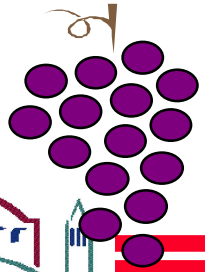




diet - 40

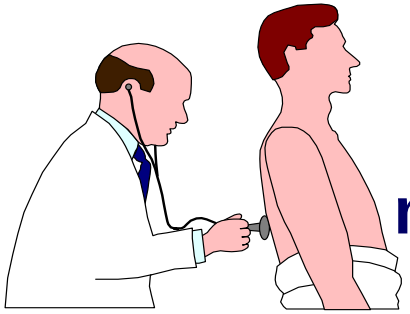


terrestrial - 28



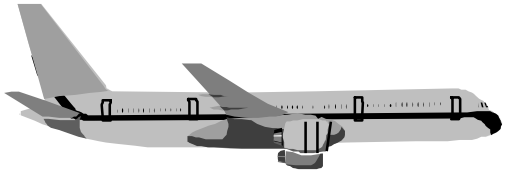
Manufactured Sources of Radiation Contribute an Average of 60 mrem/year

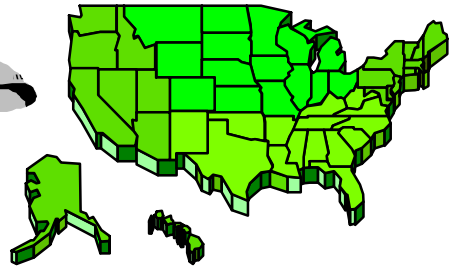
cigarette smoking - 1300 mrem lung dose



medical - 53 mrem

round trip US by air 5 mrem per trip





building materials - 3.6 mrem

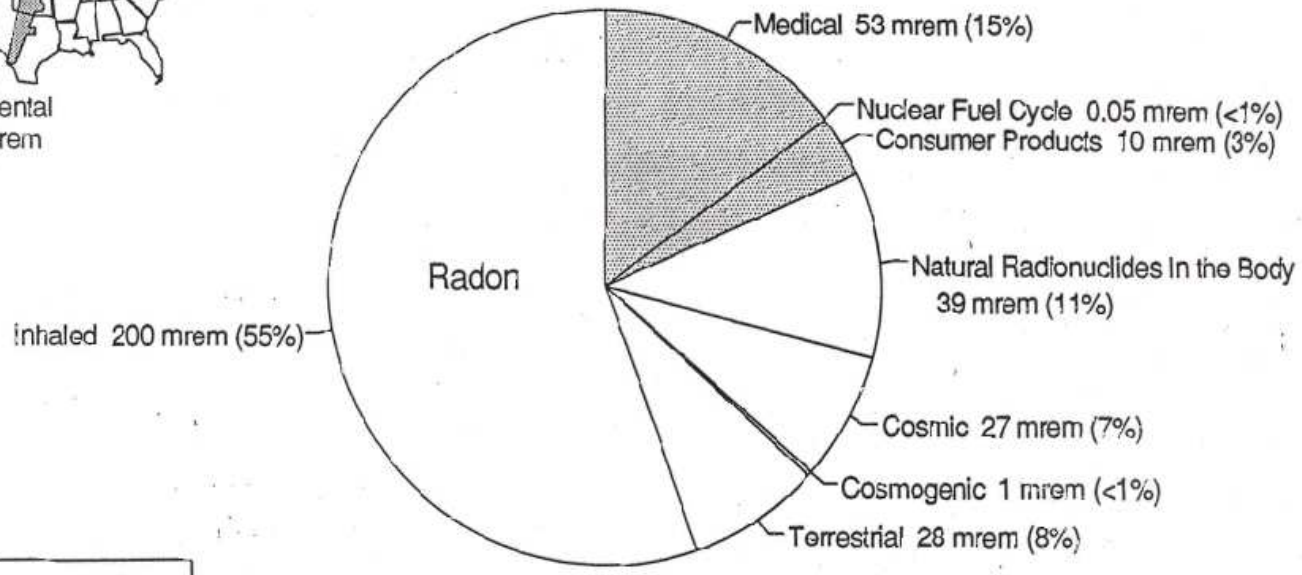
smoke detectors - 0.0001mrem

fallout < 1 mrem

AVERAGE ANNUAL RADIATION EXPOSURE
U.S. POPULATION (NON-OCCUPATIONAL)

SOURCES OF EXPOSURE

Note:
Round Trip
Transcontinental
Flight = 5 mrem



Reference: NCRP Report No. 93, Ionizing Radiation Exposure of the Population of the United States (1987).

EFFECTIVE DOSE EQUIVALENT
TOTAL = 360 mrem (Rounded)

Shaded area is manmade radiation

Natural Background = 295 mrem (82%)

Radiation Doses at LBNL

The total radiation dose at LBNL for all workers averages xx/year above the average dose of 180 mrem/year in Berkeley

Risks in Perspective

1 in 1 million chance of *fatality*

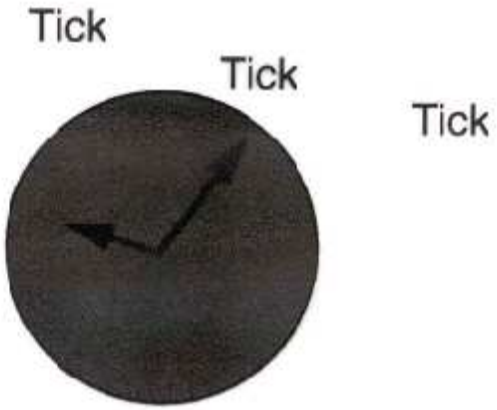
- 40 tablespoon peanut butter (aflotoxin)
- 2 days in New York City (air quality)
- 3 millirem radiation (cancer)
- 1 mile on motorcycle (collision)
- 300 miles in car (collision)
- 10 charbroiled steaks
- Smoking 1 cigarette

ALARA Techniques
As Low As Reasonably Achievable

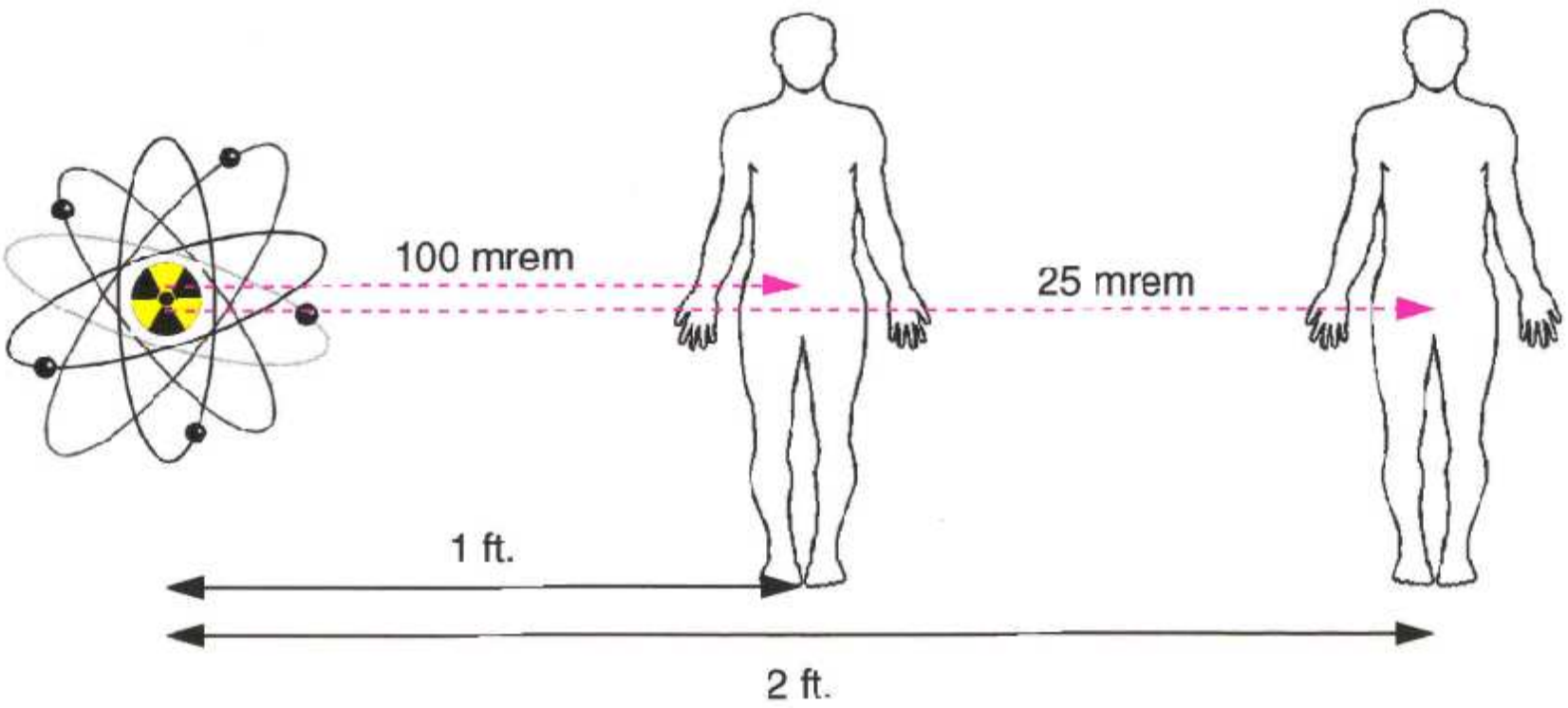
- Time
- Distance
- Shielding
- Control Methods
  - *Administrative*
  - *Engineering*

Reduce Radiation Doses

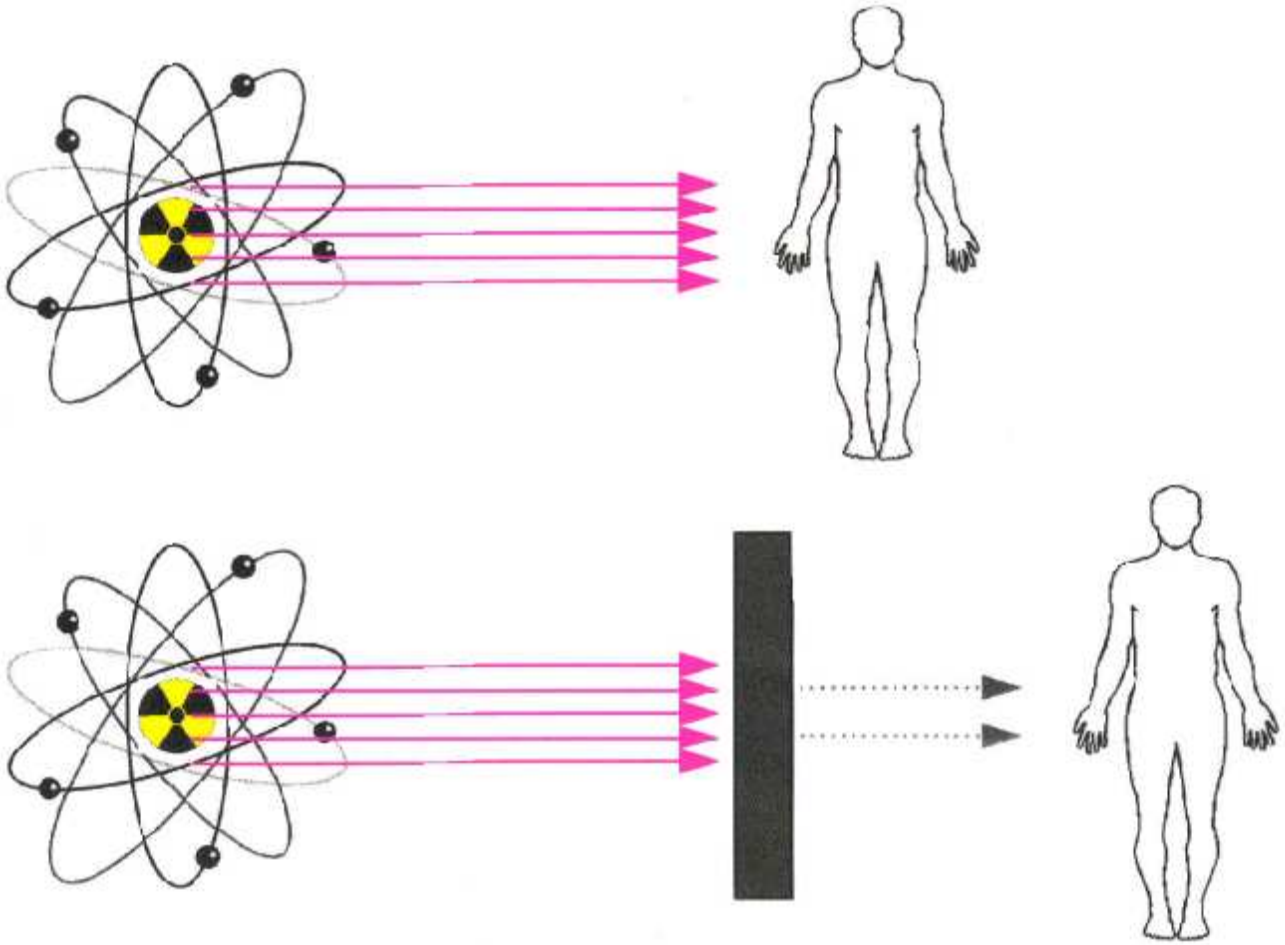
Reduce Time



Increase Distance



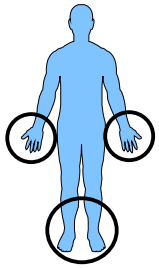
Use Shielding



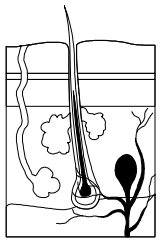
Radiation Limits

- Personnel Radiation Exposure (for radiation workers)
  - DOE Administrative Limit = 2 rem/year
  - LBNL Administrative Limit = .5 rem/yr
  - EH&S Administrative Limit = .1 rem/yr
- DOE limit for the general public and minors under the age of 18 years = 0.1 rem/yr
- Radiation Areas
  - Controlled Area – any area containing activity levels greater than background
  - Radiation Area - 5-100 mrem/hr at 30 cm
  - High Radiation Area - >100 mrem/hr at 30 cm
  - Contamination Area – any area with loose, swipeable activity

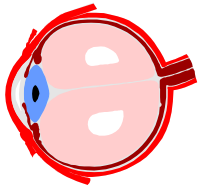
Maximum Permissible Dose for Rad Workers



Whole body, Bone marrow, Gonads — **5 rem/yr**



Extremities — **50 rem/year**



Skin — **50 rem/year**

Eyes — **15 rem/year**

Pregnant — **500 mrem/term**
50 mrem/month

Pregnant Radiation Workers

- **Fetus is most sensitive to radiation early in pregnancy**
- **Pregnant workers may, but are not required, to notify supervisor or seek guidance from Medical Services**
- **Lower dose limit for *declared* pregnant radiation worker - 0.5 rem (500 mrem) per term**
- **Alteration of radiation work may or may not be required - see supervisor**

Measuring Personnel Exposure

- Thermal Luminescent Dosimeters (TLD)
  - measures whole body dose
  - Changed quarterly- get your new one above the table in the Lobby
  - please store away from the Cyclotron, sources, etc.
  - Avoid taking on airplanes, wearing during medical X-rays, etc.
  - wear on upper part of body

If you need a dosimeter, the 88" Staff can issue you one!

Personnel Dosimeter Rules

- ☑ **Wear as required by RWA or RWP**
- ☑ **Return to Dosimetry Office during change out**
- ☑ **Front of body between neck and waist**
- ☑ **Do not mutilate or tamper with**
- ☑ **Do not expose to medical / dental / inspection x-rays**
- ☑ **Do not borrow someone else's dosimeter**
- ☑ **Do not wear at other facilities which monitor for radiation**
- ☑ **Report exposure from other facilities**
- ☑ **Report any medical radioisotope treatments**

Radiation Worker Rights and Responsibilities

Rights

- **Know what/where are the radiation hazards at every step of the job**
- **Stop work you deem unsafe**
- **Get reports of your radiation dose at Dosimetry office**
- **Notify/speak to a DOE safety inspector**
  - **Berkeley Lab Ethics Line (*You talk -We listen*)**
  - **1-800-999-9057**

Radiation Worker Rights and Responsibilities

Responsibilities

- **Know and follow the radiation safety requirements in the RWA or RWP**
  - **Job Specific Training**
  - **Sign the RWA or RWP**
- **Report unsafe conditions to supervisor**
- **Keep your radiation dose As Low As Reasonably Achievable (ALARA)**

II. DOE Postings and Definitions

Posted Areas

- Controlled Area
- No Radiological Material
- Radiological Storage Area
- Radiological Materials Area
- Radiological Work In Progress
- Radiation Area

NOTICE: Controlled Areas

Posted at the entrance to any location in which radioactive fields or material of any origin is present (blue & white)

CAUTION: Radiation Area

Posted in any area in which prompt or induced activity is between 5 and 100 mR/hr at 30 cm from the source (magenta and yellow)

DANGER: High Radiation Area

Posted in any area in which the prompt or induced activity exceeds 100 mR/hr at 30 cm. Every effort is made to make these areas inaccesible. Do not enter.

CAUTION: Contamination Area

Posted at any area in which loose, swipeable activity is present. Area is roped off. Do not enter without protective clothing and proper training.

CAUTION: Radioactive Material Area

- Posted in any area in which unsealed radioactive material is being worked on (yellow and black or magenta).
- Area is usually outlined with magenta/yellow tape.

CAUTION: Radioactive Storage Area

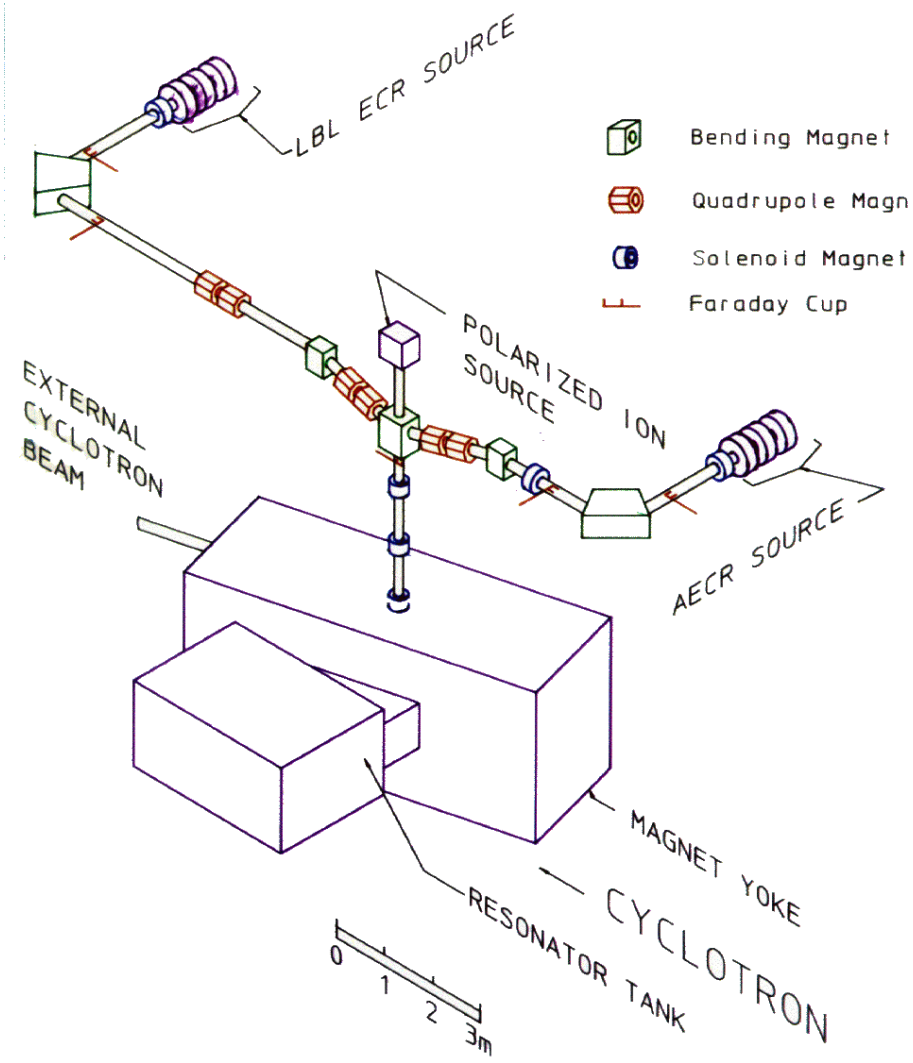
Posted in any area in which unsealed or activiated radioactive material is stored (yellow and black or magenta)

LBNL Terminology and Acronyms

EHS (Environmental Health and Safety)	The division within LBNL responsible for health and safety within LBNL
RWA (Radiological Work Authorization)	The EH&S authorization and protocols for performing ongoing radiological work at LBNL. Most work at the Cyclotron is performed under RWA 5083
RWP (Radiological Work Permit)	The EH&S authorization and protocols for performing short-term radiological work at LBNL, mostly relating to facilities.
SSA (Sealed Source Authorization)	The EH&S authorization and protocols for using sealed sources; SSA 183 covers most of the sealed sources in use in Bldg. 88.
RMA (Radiological Material Area)	A designated area for performing work using unsealed radioactive material
RSA (Radiological Storage Area)	A designated area for storing activated or potentially activated material
PERF (Prompt External Radiation Field)	88″ Cyclotron designation for running conditions in which neutrons are produced at levels high enough so that radiation areas are possible outside the locked caves
ALARA (as low as reasonably achievable)	The principal governing all radiation work at LBNL
AHD (Activity Hazard Document)	Document describing all hazards (rad and non-rad) associated with a project or piece of equipment and their mitigation

III. Radiation Hazards at the 88-Inch Cyclotron

The 88-Inch Cyclotron and its ECR Sources



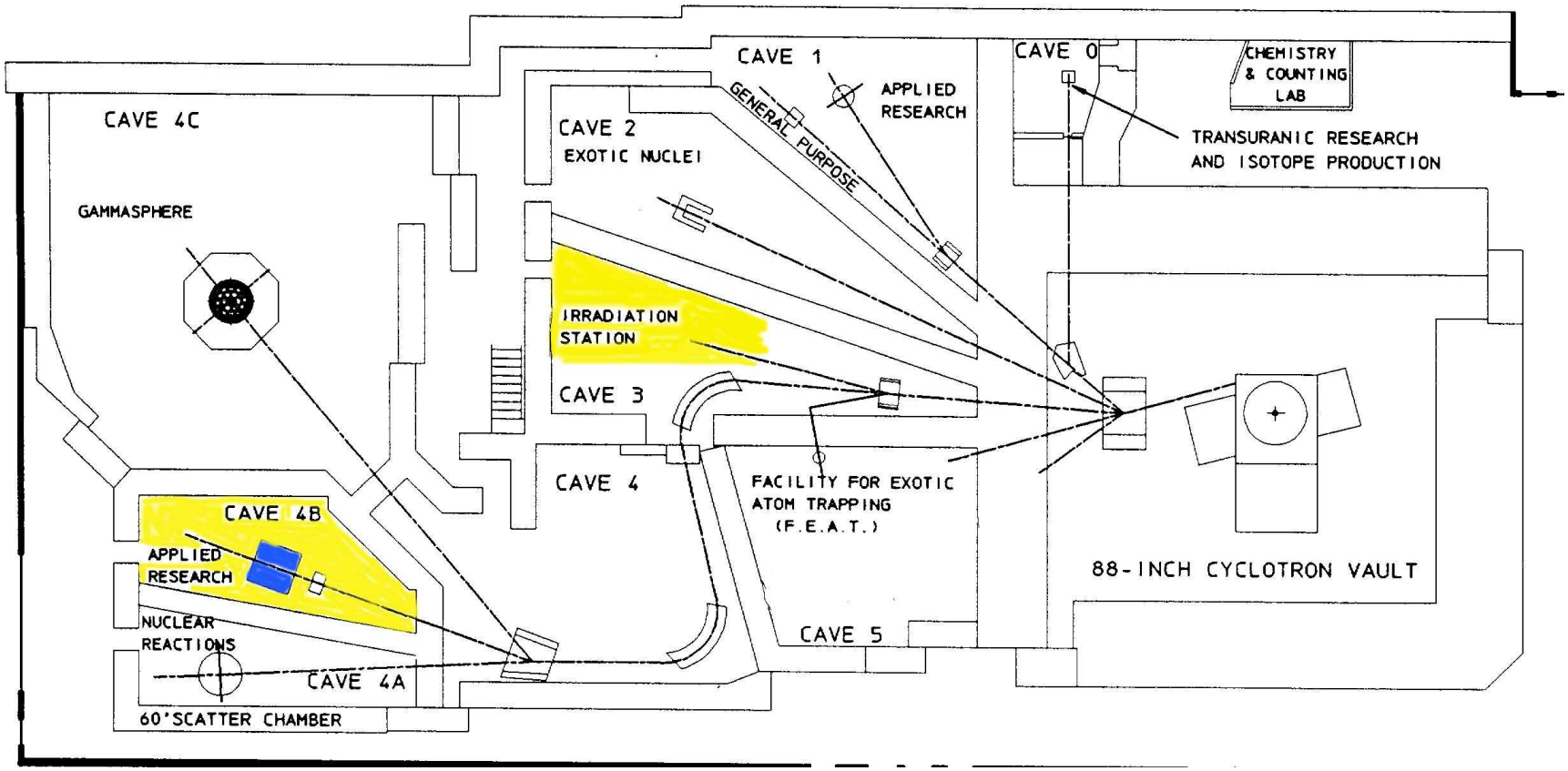
Beams Accelerated by the 88-Inch Cyclotron

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac															

Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

Elements accelerated by 88-Inch Cyclotron

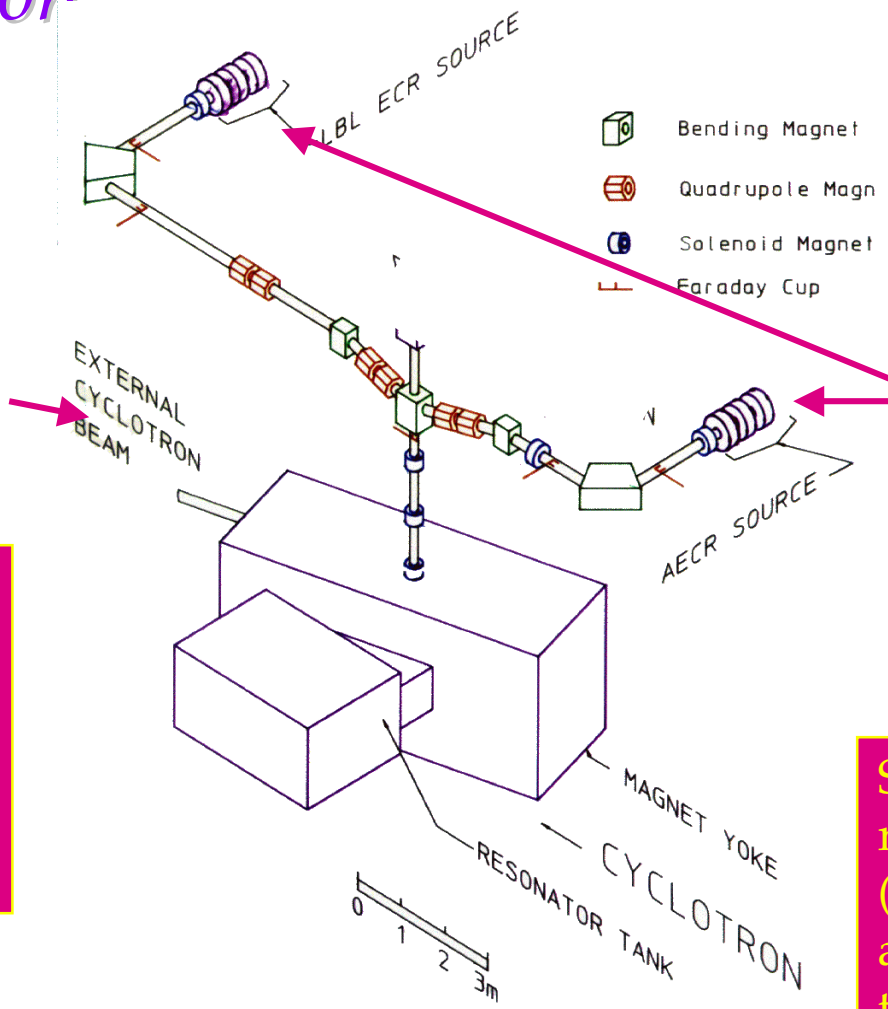
88-Inch Cyclotron Caves



Radiation Hazards you may encounter at the Cyclotron

Neutrons along the Path of the beam (ionizing) for high intensity and/or high energy runs [PROMPT]

Induced activity on targets, beamline parts, etc. anywhere designated as RSA or beamline area [INDUCED]



X-rays in area of ECR sources (non-ionizing) for all types of runs [PROMPT]

Sealed and unsealed radioactive material (including actinides and biomedical tracers)

Access to Building 88

For activation of ID badge for entry or keys, contact our Administrative Asst, x7849

- Your activated LBNL ID card gets you into the building
- 88-79 key gets you into Controlled Areas for Radiation Protection

(gates marked by sign)

Entering Controlled Areas

- In order to enter a Controlled Area for Radiation Protection unescorted, you must
  - have completed this training (or GERT) within the past two years
  - wear a LBNL-issued radiation dosimeter

    (Building 88 requirement)

Bringing in Visitors

- "Casual Visitors" are individuals visiting LBNL for a week or less who are not engaged in research or the use of LBNL facilities (not LBL employees, DOE employees or subcontractors)
  - You may escort visitors into Controlled Areas (sign them in first at Lobby)
  - If PERF is in effect, they must take GERT and be issued a TLD or the machine must be turned off

III. Radiation Hazards at the 88-Inch Cyclotron

A. Prompt Ionizing Radiation

Minimizing Exposure to Prompt Radiation

- Physical
  - Physical controls are those that are engineered into the design of the facility
- Administrative
  - Administrative controls are procedures and other paperwork designed to minimize exposure
- The 88-Inch Cyclotron uses both physical and administrative controls to minimize the chances for radiation exposure

Physical Controls - I. Shielding Blocks

- Shielding Blocks
  - a passive device to insure casual vistors aren't exposed to prompt radiation

Physical Controls - II. Gates

- Controlled Areas
  - Areas subject to possible radiation during running are locked off with a separate key from the main building key and marked with the sign at right
  - keys are given out only to personnel with TLDs
  - Anyone in a controlled area without a TLD must be signed in at front lobby and escorted

Physical Controls - III. Interlock System

- The Interlock System at the Cyclotron has been designed to be a fail-safe system based on relay logic, with a redundant parallel system based on computer logic

Interlock System, cont.

- Upon failure of any interlock function, the power is switched off to the modulator and RF System, eliminating every form of prompt radiation
  - Failures include
    - cave, Cyclotron, pit, or trench doors opening
    - run/safe switch flipped to safe
    - key removed from Control Room panel

Parts of interlock System

- Cave doors and gates
  - must be closed or beam plug in
  - some caves have inner and outer gates plus a concrete door: all must be closed

Parts of interlock System

- Run/Safe Switches
  - must be in run position (you can switch these to "Safe" while working in cave)
- Crash-off Buttons
  - WARNING: ONLY USE CRASH-OFF BUTTONS IN AN ELECTRICAL EMERGENCY OR FIRE

Administrative Controls: Building PA system

- Operators announce when Cyclotron main magnet and RF systems are coming on or when beginning a search
- Warning: Building PA system is not audible from all caves

Search and Secure

- Operators search vault and cave before tuning beam to make sure no one is inside
- Operators then close cave doors. Keys must be checked out from control room before reentering.
- If you go into a cave during an experiment, you are responsible for re-searching it before you leave. (NSD1007)

PERF Runs

- When high intensity, high energy ions are running, extra precautions are in place (PERF AHD and RWA #1083)
- Radiation locks are locked on gates accessing areas where the combined neutron/gamma field may be >2.5 mR/hr. at any location inside gate
- Radiation Areas and High Radiation Areas are marked where they exist

Color-coded map

A map is posted in the Control Room showing the locations where fields are:

- Above background and below 5 mR/hr (yellow)
- Above 5 mR/hr and below 100 mR/hr (purple)
- Above 100 mR/hr (red)

Rule of Thumb: Limit exposure to 10 mR/hr/day

This means, without measuring the field directly:

» work maximum of 2 hours/day in yellow area

» do not work in purple area without measuring field or talking to Operations Staff

» do not work in red area

PERF Runs, cont.

After determining the field in the area you need to work, sign out a Radiation Key:

- film badge number
- where you are working
- estimate of time in area
- When check key back in, give actual time in area

Neutron Detectors

- Neutron detectors are put in locations of greatest risk and read in the Control Room
  - will alarm when neutron levels are high in an area
  - you can check the fields before entering an area which may have neutrons

Portable Neutron Detector

- A portable NG-2 meter is available if you wish to check the field right at the area you will be working
  - You can also read an integrated dose on this meter

Rotating Magenta Lights

- Areas where radiation levels are 20 mR/hr. or higher will be marked by rotating magenta lights (building policy)

Warning: Be aware of potential areas which may have been missed, such as along the wall of an adjacent cave to the one running, holes on the roof, etc.

Tracking Forms

- Tracking forms are posted in the Control Room for the running experiment
- These forms will tell you
  - The beam, energy, and cave running
  - If a PERF run is in effect
  - Whether radioactive targets are being used
  - Any other safety considerations
  - Administrative limits on maximum beam current

III. Radiation Hazards at the 88-Inch Cyclotron

B. Induced Radiation

Minimizing Exposure to Induced Radiation

- Induced Activity is Likely to be Found:
  - Around Cyclotron (especially deflectors)
  - Any beamline which has recently run light ions
  - Activated targets or tested parts
  - Other parts of an unknown origin
- Controls:
  - RWAs/RWPs
  - Survey maps
  - Signs

RWAs/RWPs

- Activities using the Cyclotron or any radioactive material will be covered by a RWA (Radiation Work Authorization) or RWP (Radiation Work Permit)
  - RWAs/RWPs list authorized personnel and procedures for performing task
  - Additional safeguards which may be required

RWA 1083

- Most cyclotron runs are covered by RWA 5083, the 88-Inch Cyclotron RWA
- Exceptions include
  - any irradiated parts or activities being transported to or from another building on site
  - any chemistry
  - other special circumstances to be decided by the Health Physicist

Safeguards (may be required by RWA/RWP)

- Pocket Dosimeters
  - you can use any time you want to check the field you may be working in
  - available from Control Room
- Finger rings
  - used for measuring the dose at extremities
  - available from EH&S
  - Required by RWA 5083 if you are working in fields greater than 100 mR/hr (additional training required)

Note: Pocket dosimeters and finger rings work for gammas only. Do not use when working in a neutron field (prompt radiation)

Cave Surveys

- During the run, if you need to go into the cave
  - take a meter and check the field

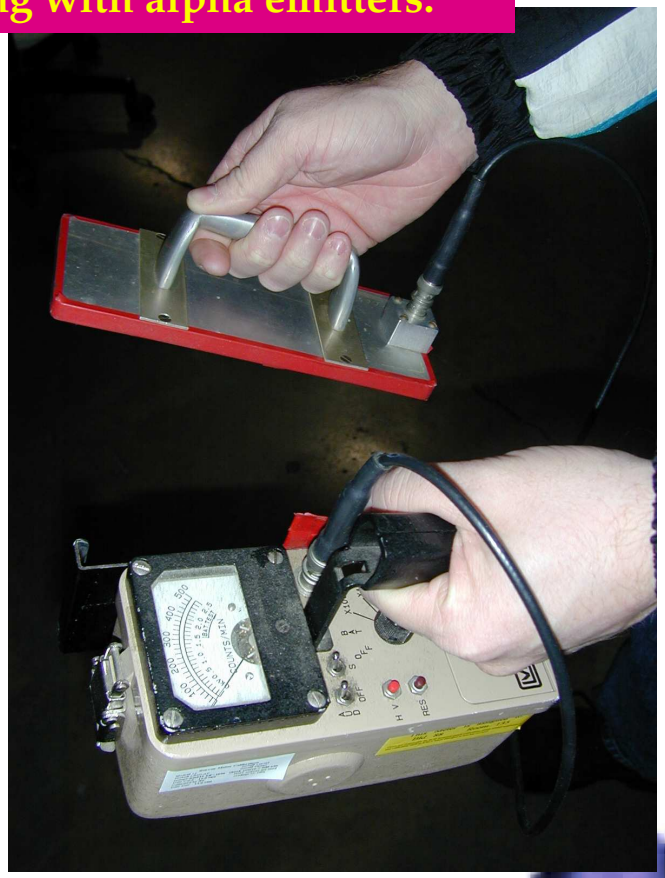
If the field is greater than 5 mR/hr at 30 cm, you cannot work in it without additional training!!

  - documentation or signs aren't necessary unless you are leaving the area unlocked and unattended
- Post-run surveys are mandatory under RWA 5083
- Following ALARA, after some PERF runs a cave may be too hot to do an immediate survey
  - In this case operators will post a "No Survey Performed" sign at entrance and lock cave if possible
  - If you need to enter a cave with a No Survey sign, check with Control Room first

Survey Meters

The Bicron RSO-50E is the instrument of choice to survey for activation products. With the back window closed it will measure gammas. With it open it will measure both beta and gamma.

Use an alpha meter when working with alpha emitters.



Posting

- During a post-run survey, if there are locations along the beamline which are greater than 5 mR at 30 cm, post with a Radiation Area sign.
- If locations are >100 mR at 30 cm, post with High Radiation Area sign.
- If the whole beamline is hot, post the entrance to the cave with the appropriate sign.

Removing material from Beamlines

- Any beamline component or irradiated part is potentially activated.
- Any material removed from a beam line should be surveyed and can only be moved by the user to an RSA or RMA. This includes targets and irradiated parts !!
- Material that was in or around a beam line must be surveyed by a Radiation Control Technician before being released from a RSA or RMA

Jerri Shoff, Peggy McMahan or Jim Morel can check any equipment which was in the beam and issue a green release tag if it is below background. If it is above background it must be shipped by EH&S or remain here until cold.

III. Radiation Hazards at the 88-Inch Cyclotron

C. Sealed radioactive sources

Radioactive Sources

- Most radioactive sources used in the building are low-level
- Radioactive sources are stored in the Cave 0 alcove, or temporarily, may be stored in a locked safe inside a cave
- Usage of all sealed sources are covered by either a SSA (Sealed Source Authorization) or RWA

You need additional training (EHS 400 & 432) to work with sealed sources at LBNL

If you want to bring in a sealed source from another location, contact Steve Sohner at EH&S Transportation

(510)-486-

III. Radiation Hazards at the 88-Inch Cyclotron

D. Unsealed Radioactive Material

Minimizing Exposure to Other Radioactive Material

- Radioactive material
  - RMAs (Radiological Material Areas)
    - various benchtops
    - Chemistry Lab (Rm. 135) hoods
    - Cave 0
  - RSAs (Radioactive Storage Areas)
    - Scattered throughout the caves
    - Cave 0 Alcove
  - Contamination Areas

Radioactive Material - RMAs

- Radioactive Material Areas (RMAs)
  - RMAs are areas (large or small) where radioactive material could be present; they are for radiological work in progress

NOTE:

You need additional training (EHS 400 & 432) to work in or around an RMA!!

RMA's are delineated with this magenta/yellow tape:

BERKELEY LAB

Radiological Storage Areas

- Material you remove from the beam can be put in a Radiological Storage Area (RSA) until released by a Rad Tech
  - As a precaution, in case there is swipeable activity:
    - put it in a double layer of plastic bag to transport it to the RSA
    - Wear gloves for protection
    - Check yourself on the hand and foot counter afterwards

Hand and foot counters are located in the Atrium, the East Alley and the Hi-Bay

Radioactive Contamination

- Contamination is when radioactivity is found where it is not intended (hands, shoes, floor, etc.)
- Do not spread contamination
  - If you don't know the source of the contamination, move immediately to an area only as far away from the spill as necessary to maintain your safety (in case of airborne contamination)
  - Stay in immediate area of contamination
- Call Control Room (x7826)
- If no one in Control Room, call LBL Emergency Number: x7911

Emergency Response – Radiation Safety

- In the event of a radiation accident involving an injured person, the first action should be *life saving*.
- SWIMS
  - Stop work and think
  - Warn others in the area
  - Isolate the spill or radiation area
  - Monitor the area
  - Secure the area

Material Resources

- Material
  - Signs and rope, tape etc. are in EH&S cabinet outside of Control Room
  - Meters are kept outside caves or on table in Hi-Bay
  - Neutron meter is kept in the Control Room

People Resources

People

- EH&S Personnel:
  - Jerri Schoff, Radiation Control Tech, x6242
    - -surveys, meters
  - Bob Fairchild, Health Physicist, x2278
    - RWAs
- 88" Operations Personnel:
  - Peggy McMahan, Research Coord., x5980
    - training, building access, TLDs
  - Dennis Collins, Deputy Head, Bldg. Manager, x7859
  - Ruth-Mary Larimer, x7844
  - Claude Lyneis, 88-Inch Cyclotron Head, x7815

Non-radiation Hazards

In an emergency, dial x7911
from any LBNL phone

Non-radiation Hazards

Non-radiation hazards at LBNL are covered by PUB-3000, the Health & Safety Guide, which can be found on the LBNL Website

- Typical hazards found at the Cyclotron:
  - High voltage
  - Magnetic fields
  - Cryogenics
  - Flammable gases
  - Low oxygen

Some experimental equipment has its own Activity Hazard Document (AHD), designed to guard against damage to either people or equipment from potential hazards

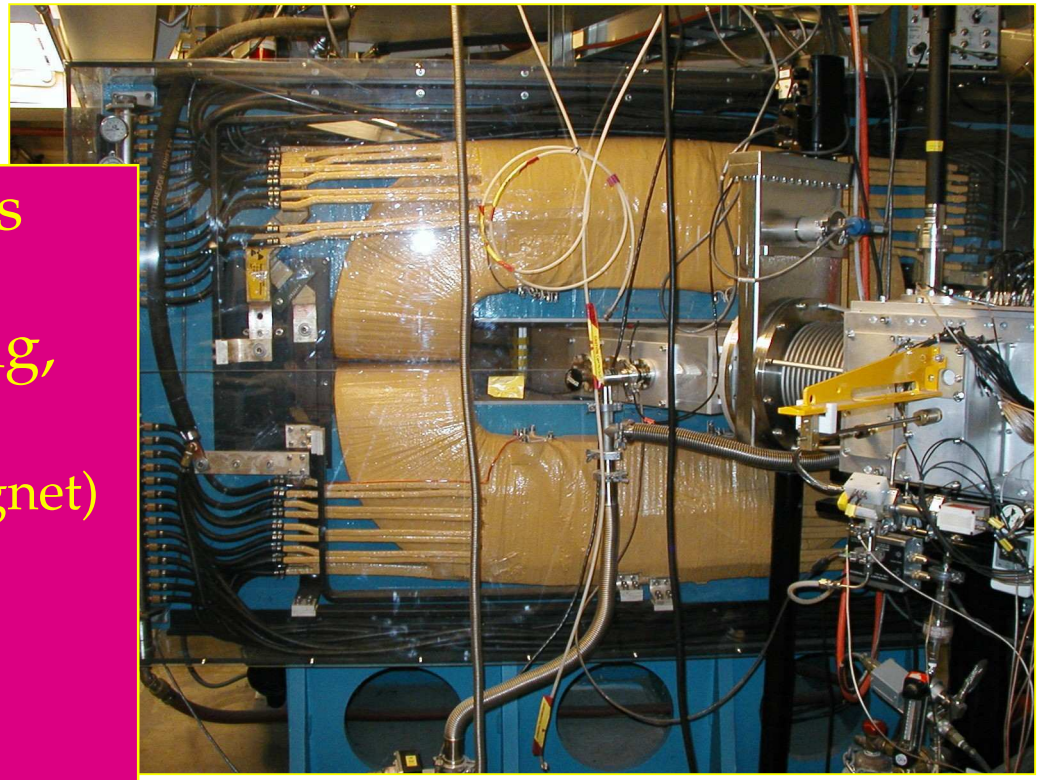
- AHDs in effect at the Cyclotron include:
  - Gammasphere
  - BGS
  - PERF runs
  - ion sources
  - RETRAP

High Voltage

- Follow common sense when dealing with high-voltage
- DO NOT:
  - Daisy chain extension cords
  - Kluge adaptors between high voltage and normal cables
  - Drape cables of any kind over sprinkler lines

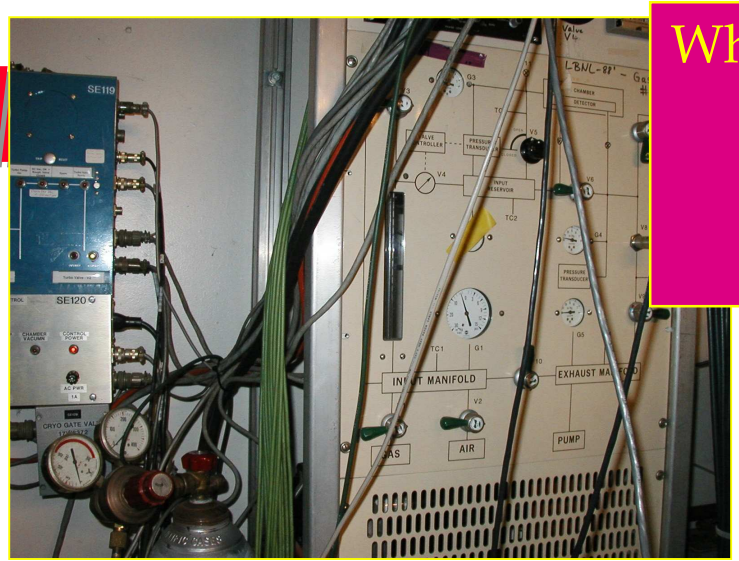
Magnetic fields

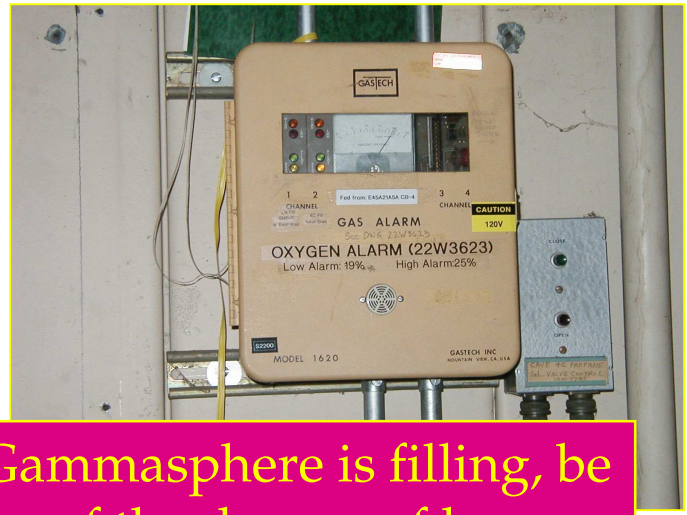
- High magnetic fields can be found many places in the building, including:
  - The vault (main magnet)
  - Cave 1 (BGS)
  - The ECR Sources
  - RETRAP
  - Beamline magnets
- Be careful with tools, credit cards and watches, etc.



One of the three BGS magnets

When using flammable gases such as isobutane, follow building procedures; calibrated alarms are required.





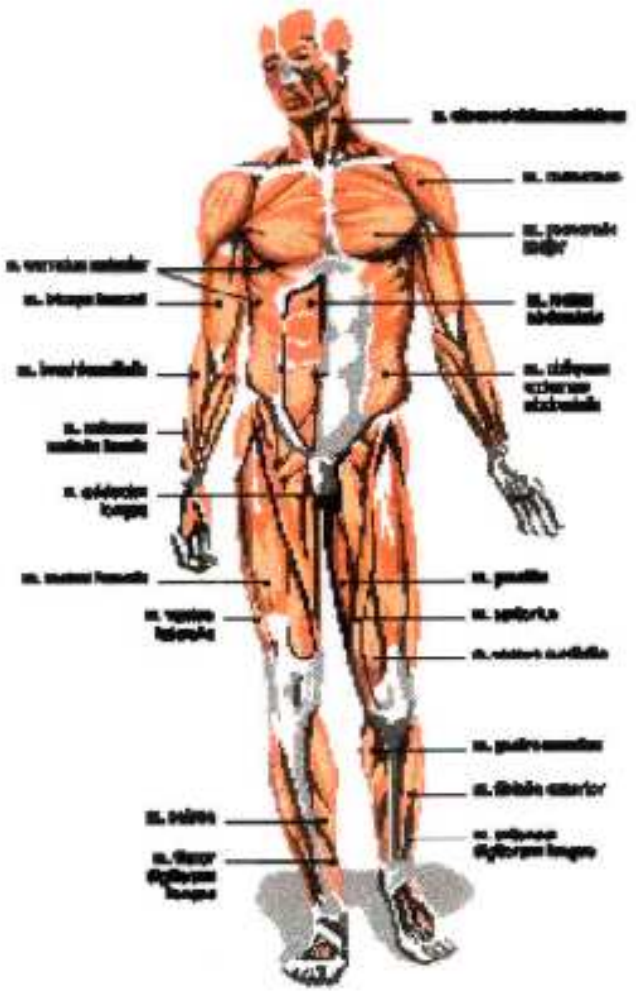
Take care when using liquid nitrogen; wear gloves and face shields when transferring and transporting

When Gammasphere is filling, be aware of the danger of low oxygen in Cave 4c; listen for the alarm

In the event of an earthquake

- In case of a major earthquake,
  - Stay calm, duck under a desk or table and hang on to it, or stand under a inner doorway or in an inside corner of a room. Stay clear of windows, tall bookcases and experimental setups. Do not use stairs or elevators while the building is shaking.
  - Leave the building by the nearest exit and proceed to the 88" parking lot assembly area
    - **check in with Peggy McMahan or a member of the Emergency Team**
    - **Await instructions before reentering building**
    - **Do not try to leave the Lab by car. Roads and access routes, if not blocked by landslides, must be kept coear for emergency vehicle use**

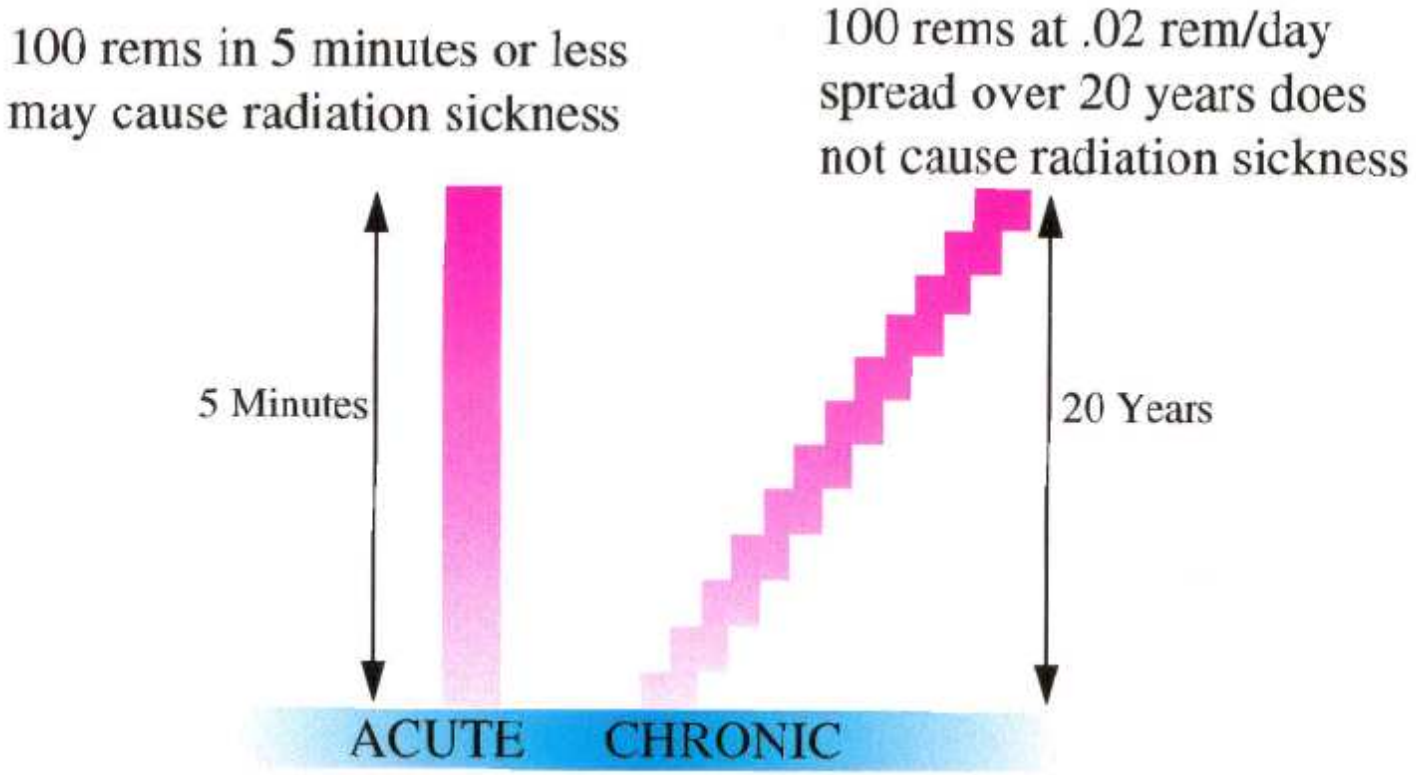
Appendix A. Biological Effects



Law of Bergonie & Tribondeau

The radiosensitivity of a tissue is directly proportional to its reproductive capacity and inversely proportional to its degree of differentiation.

Radiation Effect Depends on Total Dose and Dose Rate



Acute Localized Radiation Exposure Effects

600 – 900 rem Eye – cataracts

1000 rem Skin – radiation burn

Acute Whole Body Radiation Exposure Effects

400 rem Death to 50% of untreated individuals

Somatic Effects

Somatic effects of radiation are effects that occur in the exposed individual

Cancer

Human Evidence

1. **Radium dial painters**
   (Bone cancer)
2. **Radiologists and dentists**
   (Leukemia, skin cancer)
3. **Uranium miners**
   (Lung cancer)
4. **Atomic bomb survivors**
   (Leukemia, breast, thyroid, cancer)
5. **Ankylosing spondylitis**
   (Leukemia)
6. **Enlarged thymus**
   (Thyroid, head/neck cancer)
7. **Ringworm**
   (Leukemia, thyroid cancer)
8. **Breast irradiation**
   (Breast cancer↑ 8x)
9. **Children whose mothers were irradiate during pregnancy**
   (Leukemia)

Embryo/Fetus

1. **< 9 days – All or Nothing**
2. **10 days → 6 weeks**
3. **6 weeks → 12 weeks**
4. **12 weeks → Birth**

<u>Evidence Seen</u>
- **stunted growth**
- **small head size**
- **mental retardation**
- **low birth weight**